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Laboratory Test and Evaluation of the Litton Model F15E Molecular Sieve Oxygen Generating System

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The Litton Model F15E Molecular Sieve Oxygen Generating System, was tested for environmental and electromagnetic interference/compatibility in the UH-60A helicopter under the U.S. Army Program for Testing and Evaluation of Equipment for Aeromedical Operations. The tests were conducted using current military and industrial standards and procedures for environmental tests and electromagnetic interference/compatibility and human factors. The Litton Model F15E performed properly in the test environments. It consistently produced high concentration (greater than 90%) oxygen at an output flow of 27 lpm. The unit produces a significant amount of noise while operating. The unit is susceptible to radio frequency interference from 40-41 MHz and some broadband emissions exceeded the test criteria.

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3. SUPPORTING DOCUMENTATION

Section 1. Executive digest

There is a need to provide a continuous flow of oxygen for patient resuscitation on medical evacuation (MEDEVAC) aircraft. The present system of carrying bottled oxygen on MEDEVAC aircraft is logistically cumbersome, time critical, and potentially explosive in a combat environment. Molecular sieve oxygen generating systems (MSOGS) will eliminate supply, safety, and storage problems associated with using and securing pressurized oxygen bottles in the patient compartment of air ambulances.

The Army program for test and evaluation of aeromedical equipment uses existing military standards (MIL-STD) and collective professional expertise to test and evaluate selected medical equipment for use aboard Army aircraft. Equipment is tested to protect the patients, crew, and aircraft by eliminating problems due to environmental extremes, physical incompatibility with the aircraft, or electromagnetic interference with aircraft systems.

1.1 TEST OBJECTIVES

1.1.1 To determine if the MSOGS equipment is complete and operational per the manufacturer's operating instructions.

1.1.2 To ensure the electrical safety of the medical equipment.

1.1.3 To ensure the equipment will function as designed with various inlet air pressures and flow rates.

1.1.4 To ensure the safety of the operator, the patient, and the aircrew.

1.1.5 To assess design considerations which, potentially, could contribute to an operator error.

1.1.6 To determine if the MSOGS unit can function as designed in a low-pressure environment.

1.1.7 To determine the ability of the MSOGS equipment to withstand the vibrational stresses expected in a rotary-wing flight environment without degradation or malfunction.

1.1.8 To determine the ability of the MSOGS equipment to be stored and operated in a high-temperature environment.

1.1.9 To determine the ability of the MSOGS equipment to be stored and operated in a low-temperature environment.

1.1.10 To determine the ability of the MSOGS equipment to operate satisfactorily for short periods during exposure to highly humid conditions.

1.1.11 To assess the levels of electromagnetic emissions produced by the MSOGS equipment within selected frequency ranges.

1.1.12 To assess the minimum electromagnetic susceptibility levels of the MSOGS equipment within selected frequency ranges.

1.1.13 To assess the acoustical levels generated by the unit.

1.2 TESTING AUTHORITY

Research and Technology Work Unit Summary, dated 30 September 1991. Project number 3M463807D836, titled, Molecular Sieve Oxygen Generating Systems.

1.3 SCOPE

This test was conducted at the United States Army Aeromedical Research Laboratory (USAARL) at Fort Rucker, Alabama.

1.4 MATERIAL DESCRIPTION

A molecular sieve oxygen generator is an on-site oxygen generating machine. Coupled with a compressed air source and electrical power source, it separates oxygen from other gases. The separation is accomplished with an inert ceramic material that does not require replacement. The process is regenerative and should require little maintenance. Most oxygen generator systems use several ceramic filter beds to allow continuous operation. While one filter bed is "on-line" for the oxygen generation process, the other filter bed is cleaned and purged of nitrogen and other impurities. One is producing oxygen while another is purged of nitrogen.

The Litton* Model F-15E Molecular Sieve Oxygen Generating System is designed to provide aviator breathing oxygen for crews in the U.S. Air Force F-15 Eagle high performance fixed wing aircraft. The system has been modified to provide patient oxygen by increasing the oxygen concentration (90 percent or greater) of the air produced by the unit. Oxygen can be delivered to the patient from the generator or a 450 psi storage tank (262 liters) on the unit which provides a backup oxygen supply (BOS). The MSOGS requires a compressed air source and electrical power to produce oxygen. When installed in the UH-60 aircraft the engine

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* See list of manufacturers.

bleed air will provide the compressed air and the aircraft electrical system will provide the electrical power to operate the unit. For the laboratory tests a commercial air compressor provided compressed air. Nitrogen is exhausted from the unit through a waste gas port located on top the unit.

The Litton F-15E filters compressed air and directs it to one of two Zeolite concentrator beds. The Zeolite material traps nitrogen molecules under pressure. Each bed is filled with compressed air and pressurized. Nitrogen molecules are trapped (filtered) in the Zeolite material and oxygen molecules are vented to an internal oxygen analyzer and control valves. When the bed is filled with nitrogen, the bed is depressurized and the nitrogen is purged. If the oxygen concentration exceeds the preset concentration (90 percent or greater), it is directed to the oxygen portal or backup oxygen supply. Oxygen concentrations below the pretest-set level are exhausted from the unit.

1.5 SUMMARY OF FINDINGS

1.5.1 Electrical Safety Evaluation: All measurements were within acceptable limits. No unsafe qualities were found in the Model F15E.

1.5.2 Pressure-flow Performance: The unit will function properly with a wide range of available inlet pressure and flow conditions. If sufficient compressed air pressure or flow is not available, the unit will not produce oxygen.

1.5.3 Human Factors Evaluation: The Model F15E was found to be satisfactory in all applicable categories of the evaluation.

1.5.4 Environmental Tests: The Litton F15E can be expected to perform in a variety of environmental conditions. Its performance was found to be satisfactory in all stages of the environmental testing. The requirements for environmental tests are established in MIL-STD-810E, Methods 500.2 (altitude), 514.3 (vibration), 501.2 (high temperature), 502.2 (low temperature), and 507.2 (humidity).

1.5.5 Electromagnetic Characteristics Tests: No unsafe qualities were found in the Litton MSOGS unit. The conducted emissions and conducted susceptibility were within the guidelines specified in MIL-STD 461C and 462. The unit may be unsatisfactory in certain EMI sensitive environments. Some broadband radiated emissions exceeded the test limits. There were erratic control indications (erroneous lights) and the unit stopped producing oxygen when radiated with an electric field from 7.69 to 11.4 V/m in the 40.2 to 41.9 MHz frequency band.

1.5.6 Acoustical Analysis: The Litton MSOGS produces a significant amount of noise. Noise levels from 60 dB to 80 dB were measured from 1000 to 10,200 Hz. The peak noise level was 82.9 dB.

1.6 CONCLUSIONS

The Litton Model F15E Molecular Sieve Oxygen Generator performed properly in the test environments. It consistently produced high concentration (greater than 90 percent) oxygen at on output flow of 27 lpm. The unit produces a significant amount of noise while operating. The unit is susceptible to radio frequency interference from 40 - 41 MHz and some broadband emissions exceeded the test criteria.

Section 2. Subtests

2.1 INITIAL INSPECTION

2.1.1 Objective

To determine if the MSOGS unit is complete and operational for testing per the manufacturer's operating instructions.

2.1.2 Criteria

2.1.2.1 The physical inventory is conducted solely for investigation and documentation.

2.1.2.2 The MSOGS unit will be operated with the manufacturer's recommended power and compressed air provided. The unit will produce a gas of at least 90 percent oxygen concentration at the manufacturer's specified flow rate.

2.1.3 Test procedure

2.1.3.1 A complete physical inventory of the MSOGS unit will be completed per the manufacturer's equipment list.

2.1.3.2 An operational validation test of the MSOGS unit will be conducted per the manufacturer's operating instructions by USAARL's personnel.

2.1.4 Test findings

Upon initial testing the unit failed to produce oxygen of the desired concentration. It was returned to the manufacturer who modified the unit to produce only high concentration oxygen. After returning from the manufacturer the unit produced oxygen at greater than 90 percent oxygen concentration. Criterion met.

2.2 ELECTRICAL SAFETY EVALUATION

2.2.1 Objective

To ensure the electrical safety, by evaluation of case-to-ground resistance and case-to-ground current leakage, of the MSOGS unit.

2.2.2 Criterion

The MSOGS unit shall meet the standards established in NAFP 99 for electrical safety of medical equipment.

2.2.3 Test procedure

The MSOGS unit shall be tested with a Neurodyne-Dempsey model 431F electrical safety analyzer* IAW the procedures described in Technical Bulletin (TB) Number 38-750-2. Checks for safety concerns such as case integrity, breaks in power cord insulation, and connectors shall be performed.

2.2.4 Test findings

An electrical safety evaluation of the control box for the unit could not be performed because the electrical supply connections were not supplied with the unit. A custom control box was fabricated at USAARL to allow testing of the unit. There were no safety concerns with the electrical connectors or power lines on the unit. Criterion partially met.

2.3 PRESSURE-FLOW PERFORMANCE (Laboratory)

2.3.1 Objective

To ensure the equipment will function as designed with inlet air flow rates from 50 to 200 percent of the flow rate specified by the manufacturer.

2.3.2 Criterion

The unit will produce oxygen of at least 90 percent concentration at the manufacturer's specified flow rate.

2.3.3 Test procedure

2.3.3.1 The MSOGS unit will be operated for at least 5 minutes with air flow rates from 50 to 200 percent (in 25 percent increments) of the value specified by the manufacturer.

2.3.3.2 The oxygen percentage and flow rate of the gas produced by the generator will be measured.

2.3.4 Test findings

The MSOGS unit consistently produced high concentration oxygen (greater than 90 percent) throughout a wide range of compressed air inlet pressure and output flow rates. Since the unit uses a regulator at the compressed air inlet, the compressed air flow and oxygen output changed very little with changes in compressed air supply pressure. Several test conditions are summarized:

Inlet pressure (psi)	Oxygen flow (lpm)	Oxygen concentration
25	20	94%
35	20	94%
45	20	94%

Criterion met.

2.4 HUMAN FACTORS EVALUATION (Laboratory)

2.4.1 Objectives

2.4.1.1 To assure the safety of the operator, the potential patient, and the aircrew.

2.4.1.2 To assess the design considerations which, potentially, could contribute to an operator error.

2.4.2 Criterion

The MSOGS unit must be rated satisfactory in all major categories of the evaluation. These include visual displays, controls, maintainability, conductors, fasteners, test points, test equipment, fuses and circuit breakers, labels and coding, and safety.

2.4.3 Test procedure

2.4.3.1 The evaluation will be conducted in a laboratory under fluorescent lighting and ambient room conditions.

2.4.3.2 The MSOGS unit will be operated according to prescribed instructions through its full range of functions.

2.4.4 Test findings

The unit was found to be satisfactory in all of the applicable criteria. Several criteria were not applicable due to the custom control box and installed characteristics of this device. Criterion met.

2.5 ALTITUDE (LOW PRESSURE) TEST [IAW MIL-STD-810E, METHOD 500.3]

2.5.1 Objective

To determine if the MSOGS unit can function as designed in a low-pressure environment.

2.5.2 Criterion

The MSOGS unit will produce oxygen of at least 90 percent concentration at the specified flow rate while exposed to an altitude equivalency of 15,000 feet above sea level.

2.5.3 Test procedure

2.5.3.1 A pretest performance check will be conducted to ensure proper operation of the MSOGS unit.

2.5.3.2 The altitude test was performed in a Tenney Engineering model 64S altitude chamber*. This test is based on MIL-STD-810E, Method 500.3. The MSOGS unit was operated on the floor of the chamber. Chamber pressure was decreased to 420 mmHg (15,000 ft equivalent altitude) over a 15-minute period, held constant for 60 minutes, then raised at 1500 fpm, to ambient conditions.

2.5.3.3 A posttest performance check will be conducted to ensure proper operation of the MSOGS unit after the exposure to low pressure.

2.5.4 Test findings

2.5.4.1 The Litton MSOGS met pretest performance criterion

2.5.4.2 The unit operated properly and produced high concentration oxygen while at 15,000 feet equivalent altitude. Criterion met.

2.5.4.3 The unit operated properly after the altitude exposure. Criterion met.

2.6 VIBRATION TEST [IAW MIL-STD-810E, METHOD 514.4]

2.6.1 Objective

To determine the ability of the MSOGS unit to withstand the vibrational stresses expected in a rotary-wing environment without degradation or malfunction.

2.6.2 Criterion

The MSOGS unit will remain operational and be able to produce at least 90 percent oxygen at the specified flow rate while exposed to vibrational stresses.

2.6.3 Test procedure

2.6.3.1 A pretest performance check will be conducted to ensure proper operation of the MSOGS unit.

2.6.3.2 The vibration test was performed using an Unholtz-Dickey model TA115-40/CSTA vibration test system*. It is a single-axis system with an electromagnetic driver unit. The test consists of sinusoidal vibrations superimposed on random vibrations over a frequency range of 500 Hz, as shown below. These vibrations are derived from measurements taken on the floor under the copilot's seat in a UH-1 helicopter traveling at 120 knots. The reference spectrum breakpoints are from MIL-STD-810E, Method 514.4; reference spectrum levels are based on field measurements with a conservatism factor of 1.5. Independent tests were conducted in the X, Y, and Z-axes.

X, Y, and Z-axis

duration: 60 minutes
broadband intensity: 2.116 G_{rms}
random vibration: initial slope : 99.00 dB/oct
5 Hz level: 0.00007 $G_{sqr/Hz}$
100 Hz level: 0.0007 $G_{sqr/Hz}$
300 Hz level: 0.0007 $G_{sqr/Hz}$
500 Hz level: 0.00007 $G_{sqr/Hz}$
final slope: -99.00 dB/oct

sinusoidal vibration:
0.9500 G_{pk} at 17.00 Hz
1.4000 G_{pk} at 34.00 Hz
0.9000 G_{pk} at 51.00 Hz
0.9000 G_{pk} at 68.01 Hz

The MSOGS unit was strapped to the vibration table fixture, and its performance evaluated before, during, and after exposure to vibration.

2.6.3.3 A posttest performance check was conducted to ensure proper operation of the MSOGS unit.

2.6.4 Test findings

2.6.4.1 The pretest performance check met the criterion.

2.6.4.2 The vibration test met criterion 6.6.2.2.

2.6.4.3 The posttest performance check met the criterion

2.7 HIGH TEMPERATURE TEST (IAW MIL-STD-810E, METHOD 501.3)

2.7.1 Objective

To determine the ability of the MSOGS unit to be stored and operated in a high-temperature environment.

2.7.2 Criteria

2.7.2.1 The MSOGS unit will generate at least 90 percent oxygen at the specified flow rate during the high-temperature operation check.

2.7.2.2 The MSOGS unit will generate at least 90 percent oxygen after the high-temperature storage cycle.

2.7.3 Test procedure

2.7.3.1 A pretest performance check was conducted to ensure proper operation of the MSOGS unit.

2.7.3.2 The high-temperature test was conducted in a Tenney Engineering model ZWUL-10107D walk-in controlled environment chamber*. This test is based on MIL-STD-810E, Method 501.3. For the high-temperature operation test, the MSOGS unit was operated in the environmental chamber. The chamber temperature was raised to 49°C and the humidity stabilized at a maximum of 20 percent RH within 15 minutes. The environmental control system is capable of regulating temperature within ± 2°C and humidity within ± 5 percent RH. Temperature and humidity were held constant for 2 hours. At 30-minute intervals, the chamber door was opened briefly to check the oxygen percentage and flow rate. After the operational test, the MSOGS unit was allowed to return to ambient conditions over a 30-minute period.

2.7.3.3 A posttest performance check was conducted to ensure proper operation of the MSOGS unit.

2.7.3.4 The MSOGS unit was stored (not operated) at temperatures of 63°C for 1 hour, 71°C for 4 hours, then again at 63°C for 1 hour. The chamber and MSOGS unit were returned to ambient conditions over a 30-minute period.

2.7.3.5 A poststorage performance check was conducted to ensure proper performance of the MSOGS unit.

2.7.4 Test findings

2.7.4.1 The pretest performance check met criterion 2.7.2.1.

2.7.4.2 The Litton Model F15E performed normally during the high temperature test. Criterion met.

2.7.4.3 The posttest performance check met criterion 2.7.2.3.

2.7.4.4 The Litton Model F15E functioned properly after high temperature storage. Criterion met.

2.8 LOW TEMPERATURE TEST [IAW MIL-STD-810E, METHOD 502.3]

2.8.1 Objective

To determine the ability of the MSOGS unit to be operated and stored in a low-temperature environment.

2.8.2 Criteria

2.8.2.1 The MSOGS unit will produce at least 90 percent oxygen at the specified flow rate during the low-temperature operation check.

2.8.2.2 The MSOGS unit will produce at least 90 percent oxygen at the specified flow rate after the low-temperature storage cycle.

2.8.3 Test procedure

2.8.3.1 A pretest performance check was conducted to ensure proper operation of the MSOGS unit.

2.8.3.2 The MSOGS unit was placed on the floor of the environmental chamber and the temperature lowered to -25°C within 25 minutes. The environmental control system is capable of regulating temperature within 2°C. Humidity cannot be controlled in the chamber at freezing temperatures. The temperature was held constant for 2 hours. The chamber door was opened briefly every 30 minutes to check the percentage and flow rate of oxygen produced. The chamber temperature was raised to ambient temperature within a 30-minute period.

2.8.3.3 A posttest performance check was conducted to ensure proper operation of the MSOGS unit.

2.8.3.4 The MSOGS unit was "stored" in a nonoperational mode. The MSOGS unit was placed on the floor of the environmental test chamber and the temperature lowered to -46°C for 6 hours. The chamber was raised to ambient temperature over a 30-minute period.

2.8.3.5 A poststorage performance check was conducted to ensure proper operation of the MSOGS unit.

2.8.4 Test findings

2.8.4.1 The pretest performance check met criterion 2.8.2.1.

2.8.4.2 The Litton Model F15E performed normally during exposure to a cold environment. Criterion met.

2.8.4.3 The posttest performance check met criterion 2.8.2.3.

2.8.4.4 The MSOGS unit functioned properly after the low temperature storage test. Criterion met.

2.9 HUMIDITY TEST [IAW MIL-STD-810E, METHOD 507.3]

2.9.1 Objective

To determine the ability of the MSOGS unit to operate satisfactorily for short periods of time during exposure to highly humid conditions.

2.9.2 Criterion

The MSOGS unit will produce at least 90 percent oxygen at the specified flow while exposed to a high-humidity environment.

2.9.3 Test procedure

2.9.3.1 A pretest performance check was conducted to ensure the proper operation of the MSOGS unit.

2.9.3.2 The humidity test was conducted in a Tenney Engineering model ZWUL-10107D walk-in controlled environment chamber*. This test is based on MIL-STD-810E, Method 507.3. For the humidity test, the MSOGS unit was placed in operation on the floor of the environmental chamber. The chamber temperature was raised to a temperature of 30°C and a relative humidity of 95 percent within 25 minutes. Temperature and relative humidity were maintained for 4 hours. The environmental control system is capable of regulating temperature within ± 2°C and humidity within ± 5 percent RH. At 45-minute intervals, the performance of the oxygen generator was checked. The chamber and the MSOGS unit were returned to ambient conditions before the posttest performance validation check was conducted.

2.9.3.3 A posttest performance check was conducted to ensure the proper operation of the MSOGS unit.

2.9.4 Test findings

2.9.4.1 The pretest performance check met criterion 2.9.2.1.

2.9.4.2 No failures were noted in performance checks during exposure to a high humidity environment. Criterion met.

2.9.4.3 The posttest performance check met criterion 2.9.2.3.

2.10 ELECTROMAGNETIC CHARACTERISTICS TEST [IAW MIL-STD-461C, Notice 2, and MIL-STD-462, Notice 5]

2.10.1 Objectives

2.10.1.1 To assess the maximum levels of radiated electromagnetic emissions produced by the MSOGS unit in the 14 kHz to 12.4 GHz frequency range.

2.10.1.2 To assess the tolerances of radiated electromagnetic susceptibility of the MSOGS unit within the 10 kHz to 10 GHz electric field.

2.10.2 Criteria

2.10.2.1 The MSOGS unit will not produce emissions in excess of the limits set forth in MIL-STD-461C, Notice 2.

2.10.2.2 The MSOGS unit will not malfunction when it is subjected to radiated emissions as specified in MIL-STD-461C, Notice 2.

2.10.2.3 The MSOGS unit shall not conduct emissions in excess of the limits set forth in MIL-STD-461C, Notice 2.

2.10.2.4 The MSOGS unit shall not malfunction when it is subjected to conducted emissions as specified in MIL-STD-461C, Notice 2.

2.10.3 Test procedure

2.10.3.1 The radiated emissions test was performed according to MIL-STD-462, Notice 5, Method RE02. The MSOGS unit was positioned on a wooden test stand inside the EMI chamber, 1 meter away from the receiving antennas. The antennas are mounted for both vertical and horizontal polarities and connected to EMI receivers. The MSOGS unit was connected to an air source through a tube extended outside the chamber. While the MSOGS unit was operating, the frequency spectrum (14 kHz to 12.4 GHz) was scanned for emissions.

2.10.3.2 The radiated susceptibility test was performed according to MIL-STD-462, Notice 5, Method RS03. The MSOGS unit was positioned on a wooden test inside the EMI chamber, 1 meter away from the transmitting antennas. The antennas are mounted for both vertical and horizontal polarities and connected to radio frequency (RF) transmitters. The MSOGS unit was connected to an air source through a tube extended outside the chamber. While the MSOGS unit was operating, it was monitored for faulty operation during exposures to fields of 20 V/m from 10 kHz to 10 GHz.

2.10.3.3 The conducted emissions tests will be performed according to MIL-STD-462, Notice 3, Methods CE02 and CE04. The MSOGS unit was placed on a grounded, copper-covered workbench. The top of the workbench is 1 meter from floor level, 1.37 meters long and 0.81 meters wide. Power was supplied via a pair of line impedance stabilization networks (LISN) and a test jig. The test jig is a wooden tray with two power receptacles and two slots to hold current probes in place around power supply conductors. While the MSOGS unit was operating, the frequency range (10 kHz to 50 MHz) was scanned for emissions conducted in the power cable from the MSOGS unit.

2.10.3.4 The conducted susceptibility spike test was performed according to MIL-STD-462, Notice 5, Method CS06, on a chemical resistant counter top. Power was supplied via a customized metal connection box. The connection box has two power receptacles and four banana jacks on its front panel. Connections to the individual power lines are made in series through the banana jacks. Transient spikes of 200 volts, 10 microseconds are generated with a Solar Electronics model 8282-1 transient pulse generator* and induced onto the power leads at the connection box banana jacks. The spikes are monitored with a Tektronix 2235 oscilloscope* connected to a power receptacle on the connection box. The MSOGS unit was plugged into the other receptacle on the connection box and placed in operation. It was observed for proper operation and visual displays while it was subjected to the power line spikes.

2.10.3.5 The conducted susceptibility test was performed according to MIL-STD-462, Notice 5, Method CS02. The MSOGS unit was placed on a grounded, copper-covered workbench. Radio frequency interference was induced on the power leads and measured at the MSOGS unit power cable. The frequency of the interference is incremented over the 50 kHz to 400 MHz range while the MSOGS unit was operated. It was observed for proper operation and visual displays while it was subjected to the radio interference on the power leads. Each frequency was held for 15 seconds.

2.10.4 Test findings

2.10.4.1 During the radiated emissions test a broadband emission exceeded the specification limits. The emission at 0.175 MHz exceeded the specification by 4.2 dB. There were no narrowband emission failures. Criterion partially met.

2.10.4.2 The Litton F15E was susceptible to radio frequency interference in the following frequencies and field strengths.

Frequency	Threshold of susceptibility
40.2 MHz	7.69 V/m
41.9 MHz	11.40 V/m

2.10.4.3 No signal failures were detected during the conducted emissions test. Criterion met.

2.10.4.4 The Litton F15E was not susceptible to radio frequency interference or test spikes during the conducted susceptibility tests. Criterion met.

2.11 ACOUSTICAL ANALYSIS

2.11.1 Objective

To determine the noise hazard associated with operating the Litton Model F15E Molecular Sieve Oxygen Generating System.

2.11.2 Criterion

The Litton MSOGS will not produce a noise hazard during normal operation.

2.11.3 Test procedure

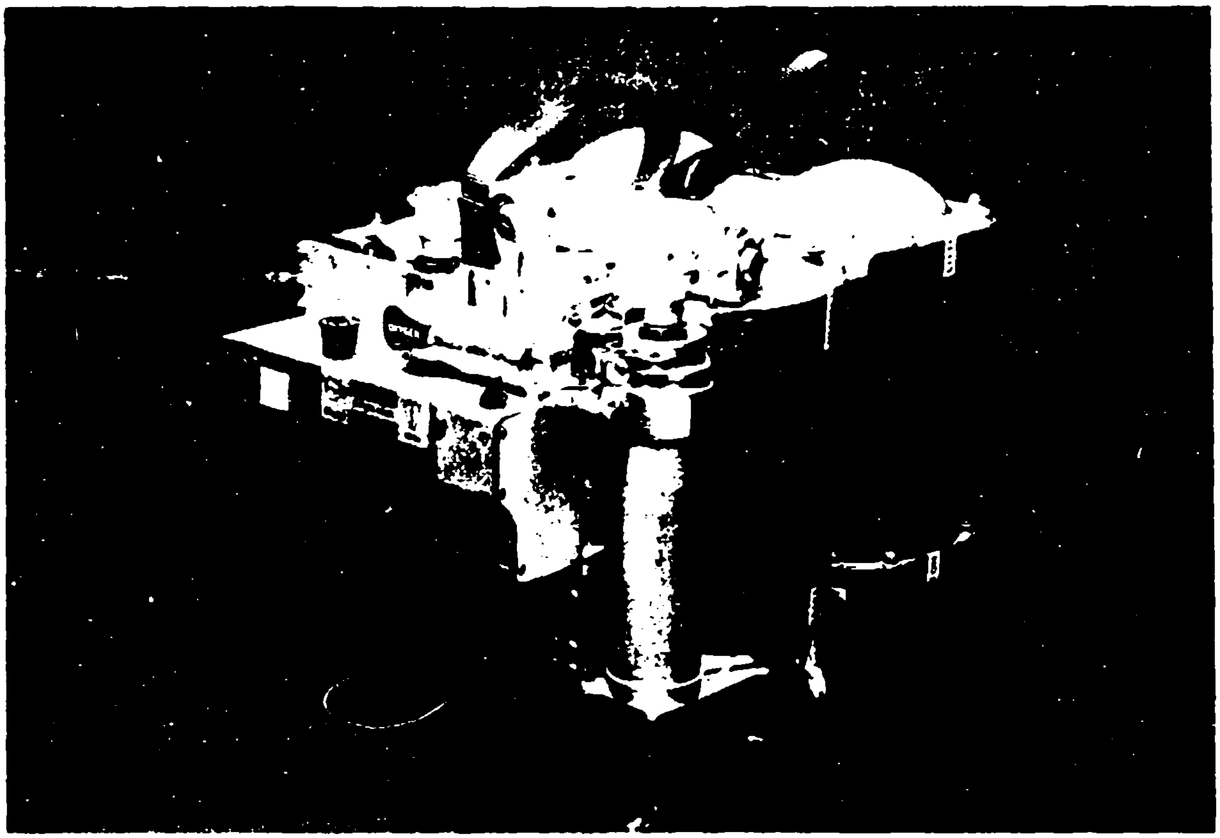
The acoustical analysis was conducted in an open outdoor area at USAARL. A Nagra recorder* was positioned 20 ft. from the MSOGS unit and connected to two microphones positioned 4 feet from the unit at an angle 90 degrees away from each other. Acoustic samples were taken north, east, south, and west of the unit. The MSOGS unit exhaust port system was not constrained or muffled during testing.

2.11.4 Test findings

The Litton Model F15E produces a noise which is subjectively loud. The peak noise level was 82.9 dB. Noise levels from 60 dB to 80 dB were produced in the 1000 Hz to 10,200 Hz range. Additional testing when the unit is installed will be required to properly evaluate this criterion for operation in the aircraft. Criterion not evaluated.

Section 3. Supporting documentation

3.1 PHOTOGRAPHIC DESCRIPTION



3.2 DETAILED TEST INFORMATION

3.2.1 Electrical safety test

Electrical Safety Test
Report Form

Nomenclature: Molecular sieve oxygen generating system
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: May 92

Performance: NA

Grounding conductor resistance (milliohms): NA

Leakage current - Case to ground (microamperes):

unit off, grounded, normal polarity	NA
unit off, ungrounded, normal polarity	NA
unit off, ungrounded, reverse polarity	NA
unit on, grounded, normal polarity	NA
unit on, ungrounded, normal polarity	NA
unit on, ungrounded, reverse polarity	NA

MAXIMUM LIMITS:

ground resistance (milliohms):	150
current (microamperes)	
current (grounded, type A unit):	10
current (ungrounded, type A unit):	100
current (grounded, type B unit):	50
current (ungrounded, type B unit):	500

Comments on item setup or checks: A control box was not provided by the manufacturer and was fabricated at USAARL. Testing of this device is not applicable to a unit installed in the aircraft.

Comments on test run (including interruptions): No unsafe qualities were noted in the unit.

Comments on other data: None

3.2.2 Human factors evaluation

Human Factors Evaluation
Report Form

Nomenclature: Molecular sieve oxygen generating system
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: May 92

Item configuration during test: Item prepared for operation.

Checklist for HFE

	RESULTS
VISUAL DISPLAYS:	NA

display type, format, content
location of displays
indicator lights
scalar displays
color coding
legends and labels
cathode ray tubes
counters
flags, go-no-go, center-null indicators

Comments: Visual displays not provided on the unit.

CONTROLS:	Satisfactory

location
characteristics of controls
labeling
control - display relationships

Comments: Oxygen cut-off switch is labelled.

TIME REQUIRED TO PREPARE FOR OPERATION (list in comment)

Comments: approximately 1 minute required for unit to complete built-in function test and begin delivering high concentration oxygen.

MAINTAINABILITY: Satisfactory

component location
component characteristics
rests and stands
covers, cases, access doors
handles
lubrication
component mounting
cord storage provisions
external accessibility
internal accessibility
list special tools required
list realistic inspection requirements
list realistic inspection intervals

Comments: Only item of user maintenance is replacement of air filter.

CONDUCTORS: Satisfactory

binding and securing
length
protection
routing
conductor coding
fabrication
connectors

Comments: Control box not provided with the unit.

FASTENERS: Satisfactory

access through inspection panel covers
enclosure fasteners
device mounting bolts and fasteners

Comments: None

TEST POINTS: Satisfactory

general
location and mounting
test point labeling and coding

Comments: None.

TEST EQUIPMENT: Satisfactory

general
equipment self-test
indicators (list in comments)
controls
positive indication of proper operation

Comments: Self test initiated when unit activated.

FUSES AND CIRCUIT BREAKERS: Satisfactory

external accessibility
easy replacement or reset by operator

Comments: Fault indicators on unit.

LABELS AND CODING: Satisfactory

placed above controls and displays
near or on the items they identify
not obscured by other equipment components
describe the function of the items they identify
readable from normal operating distance
conspicuous placards adjacent to hazardous items

Comments: Only control on unit is oxygen cut-off.

SAFETY: Satisfactory

manual
materials
fire and explosive protection
operator protection from mechanical hazards
patient protection from mechanical hazards
electrical safety (operator and patient)

Comments: No manuals supplied with the unit. Control of product oxygen will require cut-off to prevent leakage when not operating.

3.2.3 <u>Altitude Tests</u>

Altitude Test
Report Form

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: August 14, 1992

Item configuration during test:

Operating on the chamber floor and connected to the USAARL oxygen test apparatus (OTA) via portals in the chamber wall.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

Ambient conditions outside chamber:

Temperature	77°F
Humidity	66% RH
Barometric pressure	1 atm

PRETEST DATA

Pretest performance check:
Item functional (based on performance test criteria)
All OK: Pass

Installation of item in test facility:

list connections to power	115 Vac, 400 HZ 28 Vdc
list connections to simulators	Oxygen tester
list connections to dummy loads	None
list unconnected terminals	None

IN-TEST DATA

Time of test start: 0945

POSTTEST DATA

Posttest performance check:
(complete check of item and accessories)
Time of test end: 1045
Item functional (based on performance test criteria) all OK: Pass
Deviation from pretest-test: None

Comments on item setup or checks: Output flow dropped slightly from 27 lpm to 24 lpm during testing.

Comments on test run (including interruptions): None

Comments on ther data: The flow rate needle valve (located i. ~ne altitude chamber) used for adjusting output flow may have been the cause of the slight drop in output flow during testing.

3.2.4 Vibration Tests

Vibration Test
Report Form

Nomenclature: Molecular sieve oxygen generating system
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 4 Nov 92

Item configuration during test: Attached to a custom aluminum vibration table fixture.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

PRETEST DATA

Pretest performance check: All OK: Pass
Item functional (based on performance criteria)
All OK: Pass

Installation of item in test facility:

list connections to power	115 Vac, 400 Hz 28 Vdc
list connections to simulators	Oxygen test apparatus
list connections to dummy loads	None
list unconnected terminals	None

Ambient conditions

Temperature 76°F
Humidity 66% RH
Barometric pressure 1 atm

IN-TEST DATA

Data and performance checks during test:

Times and dates of test start:
X:11/4/92 1336   Y:11/5/92 0930   Z:11/5/92 1255

Time at first check:
X:1343   Y:0934   Z:1300
Item functional (based on performance test criteria): All OK: Pass
Deviation from pretest: None

Time at second check:
X:1440   Y:1023   Z:1350
Item functional (based on performance test criteria): All OK: Pass
Deviation from pretest: None

POSTTEST DATA

Time at test end:
X:1446   Y:1030   Z:1355
Posttest performance check: All OK: Pass
(complete check of item and accessories)
Item functional (based on performance test criteria): All OK: Pass
Item intact: Yes
Deviation from pretest: None

Comments on item setup or checks: None

Comments on test run (including interruptions): None

Comments on other data: None

3.2.5 <u>High Temperature Operation Test</u>

High Temperature Test
(Equipment Operating)
Report Form

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 10 Jun 92

Item configuration during test:

Operating on a wire test stand and connected to the USAARL oxygen test apparatus via portals in the chamber wall.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

Ambient conditions outside chamber:

Temperature	26°C
Humidity	79% RH
Barometric pressure	752.5 mmHg

PRETEST DATA

Pretest performance check:
Item functional (based on performance test criteria):
All OK: pass

Installation of item in test facility:

list connections to power	115 Vac, 400 Hz 28 Vdc
list connections to simulators	OTA
list connections to dummy loads	None
list unconnected terminals	None
distance from north wall (meters)	0.56
distance from south wall (meters)	1.02
distance form east wall (meters)	1.57
distance from west wall (meters)	1.45

distance from ceiling (meters) 1.19
distance from floor (meters) 0.97

Time of test start: 0820

Performance checks during test:

First check:

Time: 0850
Temperature: 49°C ± 1°C
Humidity: 15% RH ± 1% RH
Barometric pressure: 752.5 mmHg
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

Second check:

Time: 0920
Temperature: 49°C ± 1°C
Humidity: 15% RH ± 1% RH
Barometric pressure: 752.5 mmHg
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

Third check:

Time: 0950
Temperature: 49°C ± 1°C
Humidity: 15% RH ± 1% RH
Barometric pressure: 752.5 mmHg
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

POSTTEST DATA

Posttest performance check:
(complete check of item and accessories)
Time of test end: 1020
Item functional: (based on performance criteria):
All OK: Pass
Deviation from pretest: None

Comments on item setup or checks: None

Comments on test run (including interruptions): None

Comments on other data: None

3.2.6 High Temperature Storage Test

High Temperature Test
(Equipment in Storage)
Report Form

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 26 Jun 92

Item configuration during test:

Sitting on wire test stand, not operating. The unit is in storage.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

Ambient conditions outside chamber:

Temperature	28°C
Humidity	48% RH
Barometric pressure	752 mmHg

PRETEST DATA

Pretest performance check:
Item functional (based on performance criteria):
All OK: Pass

Installation of item in test facility:

list connections to power	None
list connections to simulators	None
list connections to dummy loads	None
list unconnected terminals	All
distance from north wall (meters)	0.56
distance from south wall (meters)	1.02
distance form east wall (meters)	1.57
distance from west wall (meters)	1.45
distance from ceiling (meters)	1.19
distance from floor (meters)	0.97

Time of test start: 0800
Mid-test time: 1100
Mid-test temperature: 71°C ± 1°C
Mid-test humidity: 15% RH ± 1% RH

POSTTEST DATA

Posttest performance check:
(complete check of item and accessories)
Time of test end: 1400
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

Comments on item setup or checks: None

Comments on test run (including interruptions): None

Comments on other data: None

3.2.7 Low Temperature Operation Test

Low Temperature Test
(Equipment Operating)
Report Form

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 22 Jun 92

Item configuration during test:

Operating on a wire test stand and connected to the USAARL oxygen test apparatus via portals in the chamber wall.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

Ambient conditions outside chamber:

Temperature	29°C
Humidity	59% RH
Barometric pressure	753 mmHg

PRETEST DATA

Pretest performance check:
Item functional (based on performance criteria)
All OK: Pass

Installation of item in test facility:

list connections to power	115 Vac, 400 Hz 28 Vdc
list connections to simulators	Oxygen tester
list connections to dummy loads	None
list unconnected terminals	None
distance from north wall (meters)	0.56
distance from south wall (meters)	1.02
distance form east wall (meters)	1.57
distance from west wall (meters)	1.45

distance from ceiling (meters)	1.19
distance from floor (meters)	0.97

Time of test start: 0900

Performance checks during test:

First check:

Time:	0930
Temperature:	- 25°C ± 1°C
Humidity:	NA
Barometric pressure:	753 mmHg
Item functional (based on performance criteria)	All OK: Pass
Deviation from pretest:	None

Second check:

Time:	1000
Temperature:	- 25°C ± 1°C
Humidity:	NA
Barometric pressure:	753 mmHg
Item functional (based on performance criteria)	All OK: Pass
Deviation from pretest:	None

Third check:

Time:	1030
Temperature:	- 25°C ± 1°C
Humidity:	NA
Barometric pressure:	753 mmHg
Item functional (based on performance criteria)	All OK: Pass
Deviation from pretest:	None

POSTTEST DATA

Posttest performance check:
(complete check of item and accessories)
Time of test end: 1100
Item functional (based on performance criteria)
All OK: Pass
Deviation from pretest: None

Comments on item setup or checks: None

Comments on test run (including interruptions): None

Comments on other data: None

3.2.8 Low Temperature Storage Test

Low Temperature Test
(Equipment in Storage)
Report Form

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 25 Jun 92

Item configuration during test:

Sitting on wire test stand, not operating. The unit is in storage.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

Ambient conditions outside chamber:

Temperature	27°C
Humidity	48% RH
Barometric pressure	753 mmHg

PRETEST DATA

Pretest performance check:
Item functional (based on performance criteria):
All OK: Pass

Installation of item in test facility:

list connections to power:	None
list connections to simulators:	None
list connections to dummy loads	None
list unconnected terminals	All
distance from north wall (meters)	0.56
distance from south wall (meters)	1.02
distance form east wall (meters)	1.57
distance from west wall (meters)	1.45
distance from ceiling (meters)	1.19
distance from floor (meters)	0.97

Time of test start: 0800
Mid-test time: 1100
Mid-test temperature: -46°C ± 1°C

POSTTEST DATA

Posttest performance check:
(complete check of item and accessories)
Time of test end: 1400
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

Comments on item setup or checks: None

Comments on test run (including interruptions): None

Comments on other data: None

3.2.9 Humidity Test

Humidity Test
Report Form

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 23 Jun 92

Item configuration during test:

Operating on a wire test stand and connected to the USAARL oxygen test apparatus via portals in the chamber wall.

Performance test criteria:

The unit's ability to provide a continuous flow (27 lpm) of 90% (or higher) oxygen with an input pressure of 60 psi.

Ambient conditions outside chamber:

Temperature	28°C
Humidity	45% RH
Barometric pressure	754 mmHg

PRETEST DATA

Pretest performance check:
Item functional (based on performance criteria):
All OK: Pass

Installation of item in test facility:

list connections to power	115 Vac, 400 Hz 28 Vdc
list connections to simulators	OTA
list connections to dummy loads	None
list unconnected terminals	None
distance from north wall (meters)	0.56
distance from south wall (meters)	1.02
distance form east wall (meters)	1.57
distance from west wall (meters)	1.45

distance from ceiling (meters) 1.19
distance from floor (meters) 0.97

IN-TEST DATA

Time of test start: 0830

Performance checks during test:

First check:

Time: 0915
Temperature: 29.5°C ± 1°C
Humidity: 95% RH ± 1% RH
Barometric pressure: 754 mmHg
Item functional (based on performance criteria): All OK: Pass
Deviation from pretest: None

Second check:

Time: 1000
Temperature: 29.5°C ± 1°C
Humidity: 95% RH ± 1% RH
Barometric pressure: 754 mmHg
Item functional (based on performance criteria): All OK: Pass
Deviation from pretest: None

Third check:

Time: 1045
Temperature: 29.5°C ± 1°C
Humidity: 95% RH ± 1% RH
Barometric pressure: 754 mmHg
Item functional (based on performance criteria): All OK: Pass
Deviation from pretest: None

Fourth check:

Time: 1130
Temperature: 29.5°C ± 1°C
Humidity: 95% RH ± 1% RH
Barometric pressure: 754 mmHg
Item functional (based on performance criteria): All OK: Pass
Deviation from pretest: None

Fifth check:

Time: 1215
Temperature: 29.5°C $\pm$ 1°C
Humidity: 95% RH $\pm$ 1% RH
Barometric pressure: 754 mmHg
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

POSTTEST DATA

Posttest performance check:
(complete check of item and accessories)
Time of test end: 1230
Item functional (based on performance criteria):
All OK: Pass
Deviation from pretest: None

Comments on item setup or checks: None

Comments on test run (including interruptions): None

Comments on other data: None

3.2.10

****

Electromagnetic Characteristics Testing
Evaluation of Performance

****

Nomenclature: Molecular Sieve Oxygen Generating System
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

Date of test: 23 Jun 92

****

Tests	Testing configuration(s):	Performance (Pass/Fail)
Conducted Emissions		
CE01	NA	NA
Comments:	NA	
CE02	Operating on copper bench.	Pass
Comments:	No signal failures.	
CE04	Operating on copper bench.	Pass
Comments:	No failure level emissions were detected.	
Conducted Susceptibility		
CS02	Operating on copper bench.	Pass
Comments:	Not susceptible to test signals on power conductors.	

CS06 Operating on copper test bench. Pass
Comments: Not susceptible to test spikes.

Radiated
Emissions

RE02 Operating on wooden test stand. Fail
Comments: One broadband emission in excess of limits was detected at 0.175 MHz with 4.2 dB of failure.

Radiated
Susceptibility

RS03 Operating on wooden test stand. Fail.
Comments: RS03 Failures.

Mode of Operation	Failure Frequency	Failure Field Strength
A/C	40.2 MHz	7.69 V/m
	41.9 MHz	11.4 V/m

3.2.11 Acoustical test

Acoustical Test
Report Form

Nomenclature: Molecular sieve oxygen generating system
Manufacturer: Litton
Model number: F15E
Serial number: 010001E
Military item number: None

Options installed: None

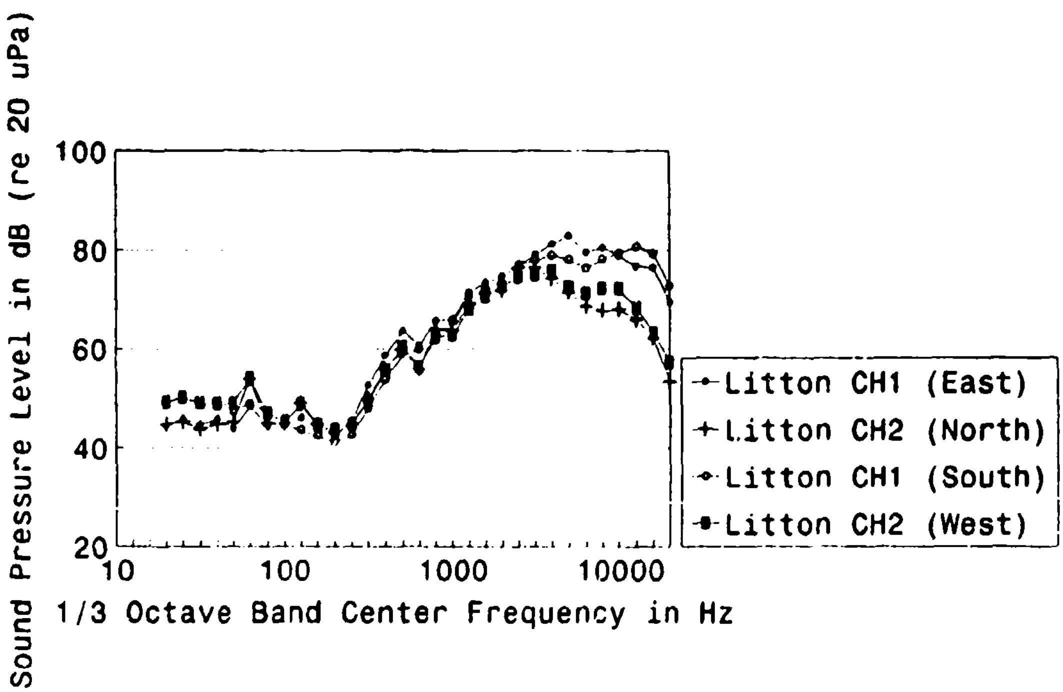
Date of test: 23 Jun 92

1/3 Octave Band Center Frequency (Hz)	Sound Pressure Level (dB) Orientation			
	East	North	South	West
20	44.5	44.8	49.1	49.2
30	45.8	45.2	50.3	50.2
40	44.7	43.8	49	49.1
50	45.9	44.8	49	48.9
60	43.9	45.2	47.4	49
70	48.4	53.9	49	54
80	44.6	45	47	47
90	45.1	44.9	44.7	45.3
100	46.1	49	43.6	48.8
200	44.3	44.7	42.5	44.6
300	42.4	43.1	41.2	43.6
400	45.3	44.8	42.5	44.8
500	52.7	49.9	48	49.3
600	58.7	55.9	53.8	55.6
700	63.6	59.9	58.8	60.3
800	60.6	55.9	59.8	56.3
900	65.6	64	62.5	62.2
1000	66.1	63.8	65.5	62.9
1100	61.3	69	70.3	67.9
1200	73.4	71.2	72.1	70.5
1300	74.7	71.7	73	72.6
1400	76.9	76.3	77	74.5
1500	79	76.4	77.8	74.8
1600	81.2	74.2	78.9	75.7
1700	82.9	71.4	78.1	72.6
1800	79.4	68.5	76.2	71
1900	80.5	67.7	78.1	72.2
10000	78.8	68	79.3	72.2

1/3 Octave Band Center Frequency (Hz)	Sound Pressure Level (dB) Orientation			
	East	North	South	West
11000	76.6	65.8	80.6	68.1
12000	76.4	62.1	79.2	63.1
13000	69.5	53.3	72.7	57.3

Note: A graphical representation of test results follows:

Sound Measurements



3.3 CRITERIA, SIGNIFICANT PROBLEMS, AND SUGGESTED IMPROVEMENTS

3.3.1 Criteria

Item No.	Criteria (source)	Remarks	Applicable subparagraph
1	The physical inventory is conducted solely for investigation and documentation.	NA	2.1.2.1
2	The Litton Model F-15E will perform consistently and accurately with an output flow of 27 lpm.	met	2.1.2.2
3	The Litton Model F-15E shall meet the standards established by NAFP 99 for electrical safety of medical equipment.	partially met	2.2.2
4	The unit will produce oxygen of at least 90% concentration at the manufacturer's specified rate.	met	2.3.2
5	The MSOGS unit must be rated satisfactory in all major categories of the human factors evaluation.	met	2.4.2
6	The Litton Model F-15E will demonstrate proper operation while exposed to an altitude equivalency of 15,000 feet above sea level.	met	2.5.2
7	The Litton Model F-15E will remain operational while exposed to vibrational stresses.	met	2.6.2
8	The Litton Model F-15E will remain operational during the high temperature operation check.	met	2.7.2.1
9	The Litton Model F-15E will remain operational after the high temperature storage.	met	2.7.2.2

10	The Litton Model F-15E will remain operational during the low temperature operation check.	met	2.8.2.1
11	The Litton Model F-15E will remain operational after the low temperature storage.	met	2.8.2.2
12	The Litton Model F-15E will remain operational while exposed to a high humidity.	met	2.9.2
13	The Litton Model F-15E will not produce emissions in excess of the limits set forth in MIL-STD-461C, Notice 2.	partially met	2.10.2.1
14	The Litton Model F-15E will not malfunction when it is subjected to radiated fields as specified in MIL-STD-461C, Notice 2.	partially met	2.10.2.2
15	The Litton Model F-15E will not conduct emissions in excess of the limits set forth in MIL-STD-461C, Notice 2.	met	2.10.2.3
16	The Litton Model F-15E will not malfunction when it is subjected to conducted emissions as specified in MIL-STD-461C, Notice 2.	met	2.10.2.4
17	The Litton MSOGS will not produce a noise hazard during normal operation.	not evaluated	2.11.2

3.3.2 Significant problems which require corrective action

The Litton Model F-15E failed to operate properly during the pretesting check for vibration testing. The unit was returned to the manufacturer for repair. The manufacturer stated that the failure was caused by a faulty flex circuit in the monitor controller. The manufacturer further stated that this problem had been identified and corrected during the F-15E MSOGS production program. The unit under test was a prototype unit that had not been modified as part of the production run corrective action.

Corrective action: Ensure any proposed procurement of Litton Model F-15E MSOGS include the modification.

3.3.3 Suggested improvements

None

3.4 REFERENCES

3.4.1 Department of Defense. 1986. EMI characteristics, requirements for equipment. Washington, DC. MIL-STD-461C, Notice 2. August.

3.4.2 Department of Defense. 1971. EMI characteristics, measurement of. Washington, DC. MIL-STD-462, Notice 5. February.

3.4.3 Department of Defense. 1983. Environmental test methods and engineering guidelines. Washington, DC. MIL-STD-810E. July.

3.4.4 Department of the Army. 1987. Maintenance management procedures for medical equipment. Washington, DC. TB 38-750-2. April.

3.5 ABBREVIATIONS

ac	alternating current
AVSCOM	U.S. Army Aviation Systems Command
AEST	aeromedical equipment suitability test
AWR	airworthiness release
BB	broadband
BPM	beats per minute
CAAF	Cairns Army Airfield
CRT	cathode ray tube
dB	decibel
dc	direct current
ECG	electrocardiograph
EMC	electromagnetic compatibility
EMI	electromagnetic interference
fpm	feet per minute
GFE	government furnished equipment
Gpk	gravity, peak
G(rms)	gravity (root mean square)
Hz	hertz
IAW	in accordance with
ITOP	in-flight test operating procedure
IGE	in-ground effect
kHz	kilohertz
KIAS	knots indicated airspeed
LCD	liquid crystal display
LED	light emitting diode
LISN	line impedance stabilization networks
MEDEVac	medical evacuation
MHz	megahertz
MIL-STD	military standard
mL	milliliter
mm	millimeter
mmHg	millimeters of mercury
m.s.l.	mean sea level
NAFP	National Association of Fire Prevention
NB	narrowband
NBC	nuclear, biological, and chemical
NiCad	nickel cadmium

NVG	night vision goggles
oct	octave
RAM	random access memory
RF	radio frequency
RH	relative humidity
ROM	read only memory
TB	technical bulletin
TFT	technical feasibility testing
T & E	test and evaluation
UES	Universal Energy Systems, Inc.
USAARL	U.S. Army Aeromedical Research Laboratory
V/m	volts per meter

3.6 LIST OF MANUFACTURERS

3.6.1 Litton Instruments and Life Support
P.O. Box 6234
Fort Worth, TX 76115

3.6.2 Neurodyne-Dempsey, Inc.
200 Arrowhead Drive
Carson City, NV 89701

3.6.3 Tenney Engineering, Inc.
1090 Springfield Road
Post Office Box 3142
Union, NJ 07083

3.6.4 Unholtz-Dickey Corporation
6 Brookside Drive
Wallingford, CT 06492

3.6.5 Solar Electronics Company
901 North Highland Avenue
Hollywood, CA 90038

3.6.6 Tektronix, Inc.
P.O. Box 500
Beaverton, OR 97077

3.6.7 Nagra Magnetics, Inc.
19 West 44th Street
Room 715
New York, NY 10036

3.7 INITIAL DISTRIBUTION

Commander, U.S. Army Natick Research,
Development and Engineering Center
ATTN: SATNC-MIL (Documents
Librarian)
Natick, MA 01760-5040

U.S. Army Communications-Electronics
Command
ATTN: AMSEL-RD-ESA-D
Fort Monmouth, NJ 07703

Commander
10th Medical Laboratory
ATTN: Audiologist
APO New York 09180

Naval Air Development Center
Technical Information Division
Technical Support Detachment
Warminster, PA 18974

Commanding Officer, Naval Medical
Research and Development Command
National Naval Medical Center
Bethesda, MD 20814-5044

Deputy Director, Defense Research
and Engineering
ATTN: Military Assistant
for Medical and Life Sciences
Washington, DC 20301-3080

Commander, U.S. Army Research
Institute of Environmental Medicine
Natick, MA 01760

Library
Naval Submarine Medical Research Lab
Box 900, Naval Sub Base
Groton, CT 06349-5900

Director, U.S. Army Human
Engineering Laboratory
ATTN: Technical Library
Aberdeen Proving Ground, MD 21005

Commander
Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

Commander
Naval Air Development Center
ATTN: Code 602-B (Mr. Brindle)
Warminster, PA 18974

Commanding Officer
Armstrong Laboratory
Wright-Patterson
Air Force Base, OH 45433-6573

Director
Army Audiology and Speech Center
Walter Reed Army Medical Center
Washington, DC 20307-5001

Commander/Director
U.S. Army Combat Surveillance
and Target Acquisition Lab
ATTN: DELCS-D
Fort Monmouth, NJ 07703-5304

Commander, U.S. Army Institute
of Dental Research
ATTN: Jean A. Setterstrom, Ph. D.
Walter Reed Army Medical Center
Washington, DC 20307-5300

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